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- RECLAMATION PLAN -
for
MILK RIVER COAL FIELD

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I. INTRODUCTION/GOALS

A study was conducted of abandoned mine sites in the Milk River Coal Field for the Montana Department of State Lands, Abandoned Mine Reclamation Bureau. Objectives and goals for this project are found in Montana's Permanent Program Strip and Underground Mine Reclamation Rules and Regulations. Specifically ARM 26.4.1235(3) states that reclamation efforts in identified abandoned mine areas should result in certain benefits as follows:

a. protection of human life, health, or safety;
b. protection of the environment, including air and water quality, abatement of erosion and sedimentation, fish, wildlife and plant habitat, visual beauty, historic or cultural resources, and recreation resources;
c. protection of public or private property;
d. abatement of adverse social and economic impacts of past coal mining on persons or property including employment, income and land values or uses, or assistance to persons disabled, displaced, or dislocated by past mining practices;
e. improvement of environmental conditions which may be considered to generally enhance the quality of human life;
f. improvement of the use of natural resources, including post-reclamation land uses which:
    1. increase the productive capability of the land to be reclaimed;
    2. enhance the use of surrounding lands consistent with existing land use plans;
    3. provide for construction or enhancement of public facilities;
    4. provide for residential, commercial, or industrial developments consistent with the needs and plans of the community in which the site is located;
g. demonstrate to the public and industry methods and technologies which can be used to reclaim areas disturbed by mining.

Additional considerations outlined in Montana regulations include eco-

nomic costs and efficiencies of reclamation.

Baseline environmental studies were conducted at five mine sites identified for study by the Department. These data were used to describe abandoned mine impacts and to develop a reclamation plan for each site. Geology, hydrology, water quality, soils, vegetation, and land use were evaluated. Results of these investigations were integrated with a literature review of appropriate reclamation technologies in order to propose the most effective and cost efficient reclamation procedure for mitigation of the respective environmental problem(s) identified at each site.

Reclamation priorities for each site were based on several factors: health and human safety, extent and severity of disturbance, efficiency of pollution abatement, benefits to the environment, and economics of each abatement strategy to accomplish the necessary control. In each case evaluated, the combined input from all disciplines contributed to an evaluation of sites as to severity and degree of mitigation necessary. From this analysis, a preferred reclamation option was recommended.

This document represents the first of a two part plan of action for abandoned mine sites in the Milk River Coal Field. The baseline studies and reclamation plan constitute this first phase. They were completed by OEA Research with subcontract assistance from Earth Resource Associates, both of Helena, Montana. Bob Ottersberg, an independent soil scientist from Bozeman, Montana contributed to the soils portion of this study. The second phase consists of engineering plans and specifications based on recommendations presented herein. The firm of Robert Peccia and Associates was responsible for preparation of these documents. Taken together, the two part plan provides sufficiently detailed information for the Department of State Lands AMR Bureau to solicit bids from contractors for reclamation work at the abandoned mine areas of concern.

II. STUDY METHODS

A. OVERVIEW OF THE STUDY PLAN (PROCESS)

Those aspects of the environment specifically evaluated in this study include geology, water resources, soils, vegetation, and land use.

Field data was collected in the fall of 1983 and supplemented by a literature review, previously collected environmental data germane to the area, and interviews with area residents. This information was evaluted and a preliminary judgement made on the impacts present at each site and the degree of reclamation necessary to reduce these impacts.

A second visit by environmental scientists, representatives of DSL, and project engineers was made to the study area in the late fall of 1983. A course of action for each site was outlined at that time and preliminary engineering data obtained. The interplay of State personnel, engineers, and environmental scientists provided for a feasible plan to be adopted.

B. METHODOLOGIES BY DISCIPLINE

1. Geology and Water Resources

Field studies in geology and water resources concentrated on understanding the area's stratigraphy and structure, locating wells, and developing an understanding at each mine site of the interrelationship of the mine workings and the geologic and hydrologic characteristics of the site and area. Geologic field data collected included attitudes of bedding planes and thicknesses and descriptions of rock units. Geomorphic study in the field consisted of mapping areas of coal waste deposits as well as areas of erosion and sediment deposition.

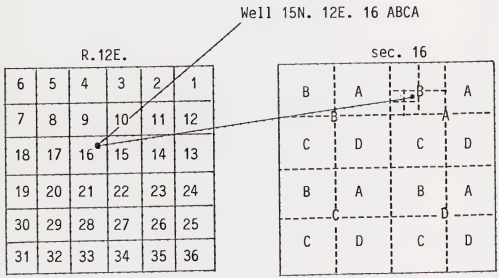
Water quality sampling was conducted in fall 1983. Field measurements of specific conductance and pH were taken with portable pH and

conductance meters. Suspended sediment load was evaluated visually. Alkalinity was measured by titration within 24 hours of sampling. Water samples were collected, preserved, kept refrigerated, and sent to Am Test, Inc. in Seattle for chemical analysis. Laboratory analysis was performed by using the inductively coupled plasma technique for metals and by standard techniques for other parameters (EPA, 1979).

Abandoned mines in the study area were located on available USGS 1:24000 or 1:62500 quadrangle maps. Each portal was located and observed to be either dry or discharging.

In this report, all data located geographically are reported using the U.S. Bureau of Land Management system of subdivision of public lands (Figure 1).

FIGURE 1. Data-point location system.



2. Health and Safety Hazards

Health and safety hazards associated with abandoned mine sites in the Milk River Coal Field were evaluated in light of two main considerations: the severity of the hazard and the immediate danger from such hazards.

Hazards evaluated in this study included open portals and adits, open or uncovered shafts, ground subsidence, potentially dangerous structures such as tipples and loading ramps, fire hazards from slack coal, erosion problems associated with toxic spoil or waste piles, and debris scattered around the sites which might cause injury.

Health and safety hazards were evaluated as to their severity and immediate threat through evaluation of their proximity and accessibility to residential or inhabited areas. Hazards located near populated areas, agricultural facilities, or main thoroughfares are considered greater threats than those located in remote, isolated, or relatively uninhabited areas.

3. Vegetation and Land Use

Vegetation resources and land use in the study area were evaluated through on-the-ground field reconnaissance and discussions with local landowners. Native and cultivated land adjacent to disturbed mine sites was defined. Vegetation colonizing disturbed sites was also identified. Information on adjacent undisturbed land, the abandoned mine sites, and surrounding land use values provided insight into the fertility of the disturbed sites, preparation of seeding mixtures and techniques for reclamation. Conversations with landowners also contributed to this formulation.

Delineation of features significant to reclamation planning was accomplished through aerial photo interpretation, a review of appropriate literature, and field mapping. Air photos of individual mine sites were evaluated as to outstanding and unique features which could potentially effect human health and safety. Subsequent to this evaluation, the mine sites were field truthed to verify features delineated on the air photos. During field evaluations, pertinent features were more accurately located on the air photos.

4. Soils and Waste Materials

Characterization of the area's soils was derived from a review of existing literature. A field investigation was used to determine reclamation potential of waste materials. Waste materials were sampled at the Radar, Perkins, and Milk River mines. Materials at the Mashke Fox mine were not sampled due to small volume and the presence of vigorous naturally established vegetation growing on the waste piles. No samples were taken from the Diehl mine which is close to and has similar looking wastes to those at the Radar mine. Samples were taken from a slack coal pile at the Avery mine which is not part of the study but close to the Diehl mine. Samples from the surface foot, and in some cases the upper three feet of waste material were collected. Analyses by Energy Laboratories, Billings, Montana, were of parameters considered to have an influence on reclamation potential. Laboratory analyses on most samples included: pH; electrical conductivity (EC); saturation percentage (SP); sand, silt, and clay content; loss on ignition (a measure of organic carbon content); and sodium adsorption ratio (SAR). Toxic element analysis of selected samples included boron, molybdenum, and selenium. Acid-base analysis, to determine liming needs, was completed on three samples. Suitability of materials as a plant growth medium was based on DSL suspect levels (Appendix A). Local soil suitability for use as a cover material was based on characteristics of adjacent soil survey map units.

III. STUDY AREA DESCRIPTION

A. LOCATION

The study area for this project is located within the Milk River Coal Field in Blaine County, north-central Montana. The five mine sites are located to the northwest and southwest of Chinook, the farthest approximately eight miles from the town (Figure 2). The coal basin is located to the north of the Bearpaw Mountains and is drained by the Milk River. The study area is located in the Great Plains and is characterized by bench topography. Relief is subdued by a cover of

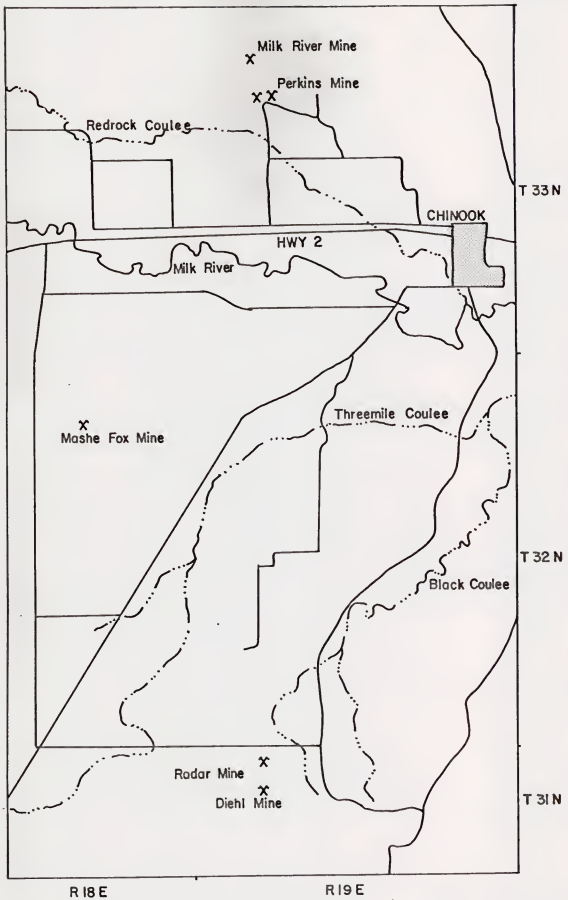


Figure 2. Study area and abandoned mines sites, Milk River Coal Basin.

glacial deposits that have produced a gently rolling upland surface. Dissection of the glaciated terrain has occurred in the past 15,000 years.

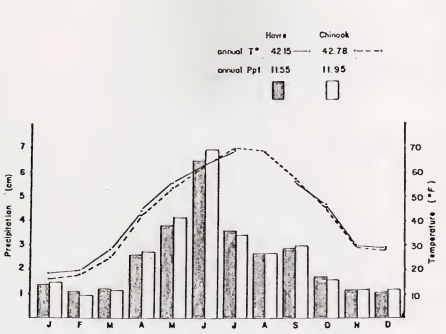
Five abandoned coal mines were investigated during the study. Two mines are northwest of Chinook. The Milk River mine (33N.12E.7) is flanked by wheat fields on an upland area owned by Wayne Torgenson of Plentywood. The Perkins mine is located on both sides of a county road in 33N.19E.7,18 on sideslope areas adjacent to the Milk River valley. The land is owned by William Pyette. Three mine sites are southwest of Chinook. The Radar and Diehl mines are on hillslopes in 31N.19E.5,6 adjacent to an unnamed tributary of Black Coulee. The Radar mine (also known as the Redekop mine) is owned by the Sorenson family. The Diehl mine is on land owned by the Peterson family. The Mashe Fox mine, owned by Mark Hagen, is a series of abandoned adits in an unnamed tributary to the Milk River in 32N.18E.11b. Gordon Hangen

B. CLIMATE

The climate of the area is considered semi-arid continental and is characterized by relatively long cold winters and mild summers. Temperatures regularly exceed 100°F during the summer and reach as low as -25°F during the winter months. The mean annual temperature for the area is 42.5°F.

Average annual precipitation for the cities of Havre and Chinook, which border the Milk River coal field is 42.15 and 47.78 cm, respectively. Approximately 75 percent of this amount occurs during the April-September growing season (Figure 3). The relationship between temperature and precipitation limits plant growth during most of the growing season unless stored water is available. Approximately 36 percent of the precipitation falls during May and June when most plant growth takes place. The average frost-free period in the areas is 125 days. Annual potential evaporation is estimated at 63.5 cm (Caprio, 1973).

FIGURE 3.



C. GEOLOGY

The Milk River coal field extends from Havre to Chinook and is located adjacent to the north and northeast flank of the Bearpaw Mountain uplift. Coal is found in the upper part of the Judith River formation. The geology and coal resources were first described by Pepperberg (1908). Subsequent geologic reports about the area have been principally concerned with the Bearpaw Mountains (Schmidt et al., 1961; Hearn, 1976) or with ground water resources (Levings, 1981 and 1982).

Geologic units in the vicinity of the mine sites include sedimentary strata of upper Cretaceous age and Quaternary glacial and fluvial deposits. The Judith River formation and overlying Bearpaw shale are the two exposed rock units in the study area and both are part of the Montana Group of upper Cretaceous age. The Judith River formation contains roughly 600 feet of alternating light-colored beds of non-marine sandstone and shales. The underlying Bearpaw shale contains approximately 700 feet of dark-gray marine shale (Levings, 1982).

The few exposures of the Judith River formation observed at the mine

sites indicate that thinly bedded siltstones with interlayered sandstone layers 4 to 8 inches thick directly overlie the coal seam. Gray shale is on top of the coarser grained rocks. The lack of a massive sandstone unit and the small thickness of overburden at some of the mines explains why subsidence is a minor problem at several sites. Small subsidence features occur generally within 200 feet of adits and are restricted to the areas of very thin overburden near adits.

The mineable coal is found near the top of the Judith River formation (Hearns, 1976). The coal is subbituminous and occurs generally in one seam. The seams are lenticular in shape and are not continuous through the area. Maximum coal thickness is nine feet. Coal production started before 1900 (Pepperberg, 1908) and continued to 1970 at one mine. The coal was not suitable for use in locomotives due to its impurities and tendency to crumble. Domestic heating was the only use made of the coal.

Glacial till in the form of ground moraine covers all the flat upland areas of the study area. A southeastward-advancing late Pleistocene ice sheet which terminated 10 to 15 miles south of the study area deposited the till (Alden, 1932). Fluvial deposits of Quaternary age fill the bottoms of the major drainages.

The regional geologic structure is a gentle eastward dip of the sedimentary rocks which has been complicated by folding, faulting, and large gravity slides associated with the Bearpaw Mountain uplift. Within the study area the Judith River formation may dip as much as 20° in association with minor folds and faults. However, the attitude of coal seams at the mine sites studied were horizontal to dipping less than 5° to the north and east.

D. SOILS

Early reconnaissance soil maps recognized one soil type, the Scobey series, at all five mine sites (Gieseker, et al., 1929). The General Soil Map of Montana recognizes differences north and south of Milk River

(Montagne, et al., 1983). North of the river soils have strongly developed argillic, natric, or calcic horizons, where as soils south of the river are less well-developed.

The county-wide soil survey (in progress) identifies further detail among study area soils (SCS, 1983). South of the Milk River, an association of the Williams and Vida soil series surrounds the Diehl, Mashke Fox, and Radar mines. These soils have thin, loam surfaces overlying light clay loam subsoils. In addition, the Williams series is underlain by a thick, loam substratum.

North of the Milk River, the soils are strongly influenced by topography and the bentonite members of the Bearpaw Shales. The Perkins mine lies in moderately steep till breaks. The surrounding soils of the Hillon and Kevin series are deep, with light clay loam textures throughout. In contrast, the Milk River mine, which lies in gently sloping till, is dominated by the Elloam and Phillips series. Both series have heavy clay loam or light clay subsoils dominated by sodium-rich montmorillonite. The Phillips series has a thin, loam surface, while the Elloam has little or no loam surface. Table 1. gives the taxonomic classifications for the series discussed above.

TABLE 1. Classification of major soils of the Milk River Coal Field.

Soil Series*	Classification	Mine Site
Elloam	Fine, montmorillonitic Borollic Natrargids	Milk River
Phillips	Fine, montmorillonitic Borollic Paleargids	Milk River
Hillon	Fine-loamy, mixed, frigid Ustic Torriorthents	Perkins
Kevin	Fine-loamy, mixed Aridic Argiborolls	Perkins
Vida	Fine-loamy, mixed Typic Argiborolls	Diehl, Mashke Fox, Radar
Williams	Fine-loamy, mixed Typic Argiborolls	Diehl, Mashke Fox, Radar

* unpublished SCS (1983)

Waste materials at the mines are generally mixed and not found as either pure coal or pure over- or interburden. However, properties of individual waste piles are largely determined by the dominant material whether predominately coal or overburden. Waste piles in the study area can be classified into three major types: slack coal, high clay, low clay. Slack coal piles exist because some coal extracted from the mine contained sufficient impurities to prohibit its use for domestic home heating. High and low clay waste piles are present depending on the type of overburden material present at the mine. Fine to medium grained sandstones, interbedded sandy shale, mudstone, siltstone, and shale are found in the Judith River formation which contains the coal (Veseth and Montagne, 1980). Thick units of bentonite contained in the Bearpaw shale lie immediately above the Judith River formation (Ross, et al., 1955). This complex of material closely associated with the coal seams contributes to the variety of high and low clay waste material observed.

E. LAND USE AND VEGETATION

The predominate land use within the Milk River Coal Field is agriculture. Spring and winter wheat, barley, and oats are the principal commodities produced. Most of the gently sloping, more productive land is cropped. Adjacent untillable land supports rangeland and is used for cattle grazing. Livestock is a secondary but still an important industry in the area, with county-wide production ranking it seventh among counties in the State (Montana Dept. of Agriculture, 1983).

A combination of precipitation and soil conditions dictate vegetation composition on untilled areas. On medium to moderately fine soils one finds grasslands composed principally of central plains plant species such as blue grama (Bouteloua gracilis), western wheatgrass (Agropyron smithii), needle-and-thread (Stipa comata) and threadleaf and needleleaf sedges (Carex filifolia and Carex eleocharis). Certain clay dominated sites support similar species with the exception of needle-and-thread. Isolated soils with coarse textured sandy surface horizons contain needle-and-thread, prairie sandreed (Calamovilfa

longifolia) and threadleaf sedge. The existing carrying capacity for grasslands in the Milk River Coal Field is 4.5 acres per cow month with a potential for 3.5 acres/cow month.

Several of the mines studied are situated adjacent to or in the numerous coulees found throughout the area. These drainages are only seasonally wet but sustain enough year-long subsurface moisture to support dense stands of western snowberry (Symphoricarpos occidentalis) and Wood's rose (Rosa woodsii). They are also the preferred habitat for most game and nongame animals inhabiting this area.

F. WATER RESOURCES

The Judith River formation is the important shallow aquifer in the Chinook area. Ground water movement in the study area is generally from the recharge areas in the south (Bearpaw Mountains) and north (plains area) to discharge areas along the Milk River valley. Recharge is mainly from infiltration of precipitation along the outcrops. Vertical leakage into or out of the formation is minimal because of the very low permeability of the overlying Bearpaw shale and underlying Clagget shale (Levings, 1982). The Judith River formation yield is about 10 gallons per minute (Levings, 1981).

Shallow ground water quality in the study area is very poor, and water from alluvium in small drainages and from the Judith River formation is not used for drinking. The salinity of water reported for seven wells completed in the Judith River formation and located in the study area is very high. Specific conductance ranged from 2130 to 8400 umhos/cm and average 4480 umhos/cm (Levings, 1981). Two farmers contacted during the study also reported that shallow ground water quality was not good for domestic use. At a third site (Milk River mine), drinking water was hauled to the mine and stored in a concrete cistern.

Surface water, particularly the Milk River, is an important resource in the study area. It is used for irrigation and municipal water supply. In the vicinity of all the abandoned mine sites, there is no surface

water with the exception of the mine drainage at the Radar mine. The nearest drainages to the mine sites are small and ephemeral. Runoff from several of the mine areas is collected in stock ponds. No water quality problems were reported and no water quality testing was done of surface water.

IV. ENVIRONMENTAL IMPACTS

A. SITE SPECIFIC IMPACTS

1. Milk River Mine

The Milk River mine is located four miles northwest of Chinook in 33N.14E.7. It is the only mine studied at which vertical shafts were used to intercept the coal seam. Prior to its abandonment in 1970, due to new Occupational Safety and Health Administation (OSHA) regulations, the mine was the sole source of local coal for communities as far away as Malta. The mine area proper is on a flat upland surface. Land surrounding the mine site is used as cropland. There are no mine-related structures which remain above ground except for a scale house and several service buildings.

All but one of the mine's shafts have been filled with refuse and they present no safety hazards. The one remaining open shaft is 800 feet north of the mine proper, at the bottom of an adjacent coulee, and does present a significant safety hazard. It is five feet in diameter and over 150 feet deep. Water is encountered at 106 feet.

South of the mine's remaining buildings, approximately seven acres of land are covered with two to three feet of partially vegetated coal waste. This material is hummocky and not tillable. It has a sandy loam texture which is unusual compared with the predominately clayey non-coal wastes found throughout the Milk River Coal Field. The Sodium Absorption Ratio (SAR) (Appendix A, Table B, Sample 10) is moderately high but below suspect levels for this coarse of a texture. Salt and sodium are not a significant problem at this site and the waste

is only moderately acidic. Elevated levels of boron are present in portions of these waste materials. The entire mine site's current use as a junkyard is a bigger impediment than this coal waste to eventual use as farm and ranch land. The adjacent landowner has expressed an interest in buying and farming the site if a fair price could be obtained.

In summary, the mining impacts at the Milk River mine are one open air shaft, which constitutes a significant safety hazard, and the loss of seven acres of potentially tillable land. The mine-related buildings are currently in use and present no hazards at this time.

2. Perkins Mines

The Perkins mines are approximately three miles northwest of Chinook, 33N.19E.7. The mine site is divided north-south by a county road. Two residences and an equipment shop are immediately adjacent to these mines. For discussion purposes the mine sites are divided into east and west mines corresponding to the side of the road on which they are located.

The east mine consists of several collapsed adits, one large waste pile near the landowner's home, several foundations, several minor subsidence features, and an area of approximately four acres, which is covered with coal waste material. The majority of this waste material exists on gentle terrain suitable for dryland crops. The remainder occurs on the steep side slope of an adjacent coulee. Additional well-vegetated spoils piles occur at the bottom of this coulee.

Analysis of the waste material (Appendix A, Table B, Samples 6, 7, 8) indicates that the large pile is saline below the surface with moderately high saturation percentages (SP). The SAR is not a problem due to its coarse texture. Based upon DSL guidelines, the boron levels at this site (18.6 ppm) are high enough to be potentially injurious to vegetation.

A pile of porcellinite or scoria adjacent to the county road is apparently burned waste material. This material has been excavated in the past for road surfacing. At least a portion was transported to Havre to surface their high school track.

One adit at the east Perkins mine is actively collapsing and since 1975 has exposed about six feet of a rubber gas line servicing the landowner's home. Other subsidence features appear stable and do not pose a safety hazard. The site is dry.

The west Perkins Mine consists of several collapsed adits located in an ephemeral drainage. The total disturbance area at this mine, including one relatively large and several small waste piles and mine debris, covers about two acres. An adjacent waste dump to the east exists on a coulee sideslope. This site is also dry.

The waste material at this site contains clayey material. Expansive dominated sodium clays (bentonite) may be present as suggested by the abundant cracks present on the dry surface of some clay-rich wastes. Analysis (Appendix A, Table B, sample 9) showed that the dark gray waste pile east of the adit has a high clay content and high SAR and SP levels. Elevated levels of boron were also noted.

The impacts at both Perkins mines include safety hazards associated with active subsidence and the resulting exposed gas line and the loss of about six acres of land suitable for agriculture.

3. Mashke Fox Mine

The Mashke Fox mine is located approximately five miles southwest of Chinook in 32N.R18E.11. The mine site consists of several collapsed adits along both sides of a small, unnamed ephemeral tributary to the Milk River. Cropland surrounds this site on the level uplands. The only impacts that remain at this site are one small waste pile, three air shafts, and several subsidence features. All adits are collapsed and most are completely closed. The small waste pile and adit locations are

well vegetated indicating an absence of toxic elements and adequate fertility.

The three air shafts are located on level ground above the drainage on a line which extends 250 feet west of the small waste pile. One of the shafts has been filled with boulders while the other two are five feet in diameter and six feet and 25 feet deep respectively. These latter two open shafts pose an obvious safety hazard. Several subsidence features up to 15 feet in diameter and three feet deep exist at other locations in the area. Some have been filled with boulders and all appear stable. One potentially active subsidence feature exists east of the drainage in cropland. Yearly plowing over this feature appears to keep it filled thereby reducing any potential hazard.

The only apparent impact at the Mashke Fox Mine is the safety hazard associated with the two open air shafts. Subsidence activity appears to have stabilized.

4. Radar (Redekop) Mine

The Radar Mine is located eight miles southwest of Chinook in 31N.18E.5,6. It is situated on a hillslope above a small ephemeral drainage. The mine site consists of several adits, associated coal waste piles, mine debris, and two open air shafts. The mine was worked until abandonment for unknown reasons in the mid-1960's. The adits are partially collapsed. There are two open shafts at the site. One of the two is open to a depth of 12 feet and then constricts and continues another 15+ feet deeper. Although fencing surrounds the opening, access is still easily possible. The other shaft is partially filled with trash.

Coal waste is concentrated in several locations. These wastes consist of small amounts of coal and a large quantity of expansive clays with high SAR and SP values (Appendix A, Table B, samples 3, 4, 5). Elevated boron and selenium levels were also noted for these wastes.

This is the only site studied which has any mine drainage. This drainage seeps from the two adits at the northeast side of the mine area. The underground workings are partially flooded because the coal seam dips down to the northeast into the hillslope, and therefore ground water is impounded in the mine. The landowner's report that the mine was pumped confirms this analysis. Ground water discharge at the mine most probably is recharged from infiltration into cropland on level terrain above the mine in 31N.11E.5c.. Seepage from this site was estimated at 2 gallons per minute on September 26, 1983. Water-logging and salt deposits are a problem on about one-half acre of land downstream of the adits.

The quality of the mine drainage is extremely poor (Table 2). Total dissolved solids exceed 12,000 mg/l with sulfate and sodium being the dominant ions. The pH is a neutral 6.9. Other constituents whose high concentrations are of concern are nitrate, boron, manganese, and strontium. The water is definitely unsuitable for any domestic, stock, or irrigation use, and the landowner diverts the mine drainage to an impoundment below the mine site to prevent contamination of other stock watering sources.

TABLE 2. Water quality of mine drainage from the Radar Mine.

Sample	Earth Resouce 9-26-83 (measurements in mg/l unless noted)	DSL 10-31-79
Field pH	6.9	-
Field specific conductance (in umhos/cm)	> 5000	-
Field temperature	51°F	-
Aluminum	< 0.15	-
Antimony	< 0.15	< 0.2
Arsenic	< 0.30	-
Barium	0.016	-
Beryllium	< 0.003	-
Bismuth	< 0.5	-
Boron	2.53	-
Cadmium	< 0.025	-
Calcium	320	-
Chromium	< 0.03	-
Cobalt	< 0.02	-

Table 2. concluded.

Sample	Earth Resouce 9-26-83 (measurements in mg/l unless noted)	DSL 10-31-79
Copper	< 0.015	-
Iron	0.05	0.27
Lead	< 0.08	-
Magnesium	580	-
Manganese	0.24	0.34
Molybdenum	< 0.04	-
Nickel	< 0.025	-
Nitrate + Nitrite as N	411	-
Phosphorous	1.10	-
Potassium	10.6	-
Silicon	11.6	-
Silver	< 0.03	-
Sodium	3200	-
Sulfate	8500	-
Strontium	9.02	-
Tin	< 0.03	-
Titanium	0.010	-
Zinc	0.029	-

As mentioned, shallow ground water in the study is generally of very poor quality, and the mine drainage is of even poorer quality. It is thought that the high nitrate levels are caused by excessive fertilizer application on the cropland above the mine, but the high concentrations of other paramters can only be attributed to seepage through the mine workings. The upper part of the mine is not flooded and acid and sulfate are generated there by oxidation of the coal. The local ground water buffers this process such that acidity is not a problem, but the levels of sulfate, manganese, boron, and strontium are increased by leaching through the mine workings.

In summary, the impacts at the Radar Mine are non-acidic mine drainage of extremely poor quality, two open air shafts, several open adits, and the loss of about 3.5 acres of grazing land due to coal waste piles and waterlogging.

5. Diehl Mine

The Diehl Mine is located in 31N.18E.5,6, 100 feet south of the Radar mine on the same hillslope. The site has two partially collapsed adits with associated waste piles. Both adits have subsidence features above them.

Coal waste materials at the Diehl site have the same appearance as those at the Radar mine. Samples taken at the Radar represent this site. The possibility of expansive clays are suggested here by the presence of cracked surfaces. Waste material high in clay content is unvegetated. An adjacent overburden pile fronting one of the adits contains sandier textures and has revegetated satisfactorily.

The impacts at the Diehl mine site are the safety hazard associated with collapsing adits, subsidence, and the loss of less than one acre of rangeland.

V. TECHNOLOGICALLY FEASIBLE ABATEMENT METHODS

A. MINE DRAINAGE

Mine drainage occurs only at the Radar mine. Although this drainage is not acidic, it is forming through the same process (oxidation of pyrite) which produces acid mine drainage (AMD) at other abandoned coal mines in the state. Therefore, the feasible abatement methods are the same as those recommended in other studies dealing with AMD (OEA Research, 1984; McArthur, 1970).

Sealing mines with hydraulic seals and infiltration control by alternate cropping are the two methods which are the most appropriate for most Montana mines studied to date. Not every AMD problem warrants abatement, however. Mine sealing is considered feasible only when the severity of the impact is high. Alternate cropping is cheaper and is considered in situations with less severe impacts. However, neither abatment procedure is recommended for the Radar mine because the

drainage is not acidic and the environmental impact is low.

B. STREAM CHANNEL RECONSTRUCTION

Streams and drainages impacted by mine dumps will necessarily require some form of reconstruction to maintain drainage integrity and to provide for a successful reclamation program. All streams which cross mines in the study area are very small ephemeral drainages with grassed channels. Given this, the following presents general techniques for ephemeral channel reconstruction which are applicable to the Milk River area.

Channel reconstruction will typically coincide with other land-shaping reclamation activities. For the small drainages encountered at the mine sites, the critical features of design and construction are gradient and revegetation.

Channel gradients should not exceed the preexisting gradient and channels should be blended into the undisturbed drainage net with a concave longitudinal profile. Channel size will dictate the size of equipment to be used. The type of vegetation reestablished in a channel is important in determining the degree of erosion control provided by the channel. The coulee seed mix recommended below should be used for reseeding stream channels.

C. SUBSIDENCE

Proven techniques for control or elimination of subsidence are varied but generally fall into the categories listed below:

a. fill subsidence voids as they occur;
b. destroy pillars and stiff roof sections by controlled blasting;
c. backfill mines with suitable soils or mine wastes.

All mines in the study area are in rural areas and subsidence problems present little problem to local residents. Therefore, backfilling of

subsidence features is the recommended procedure because of its low cost.

Backfilling should be done with non-acidic and non-saline material if filling will occur in wet areas. Any mine debris or coal waste can be backfilled into dry areas. Mounding of suitable topsoil material over subsidence features will promote runoff away from the former depression and therefore reduce the potential for future subsidence.

At several mine sites, collapse of thin overburden over adits is recommended where the roof material is actively caving in.

D. HEALTH AND SAFETY HAZARDS

The major impacts to health and safety related to abandoned mines in the Milk River Coal Field are open shafts and adits. Impacts of lesser significance include subsidence, shallow excavations, old structures, and scattered debris.

Candidate methodologies for closing open shafts and adits are backfilling and/or sealing with concrete. On-site materials are suitable for fill and concrete can be dry-batched at Chinook and mixed on site. Demolition and disposal is the only feasible method for eliminating structures and debris. Slack and/or waste piles can be dispersed, amended, and recontoured, or can be removed and wasted elsewhere.

E. COAL WASTE SITE AND SOIL RECLAMATION

1. General Character of Waste Material

The main constraints to waste site reclamation result from the characteristics inherent in the three types of waste material found at the mine sites. Table 3 summarizes these constraints by type of waste material.

Table 3. Limitations to reclamation for the three types of waste material found during this investigation.

Waste Pile Type	pH	SAR	Other
Coal-rich waste	low	-	Coarse textures, elevated boron
High clay	slightly low	high	possible bentonite, elevated boron
Low clay	slightly low	low	elevated boron

The slightly low to low pH associated with waste piles in the Milk River coal field can best be treated by either mixing the material with uncontaminated soil or by liming.

A combination of liming and mixing is recommended in areas where a thin veneer of waste covers the original soil surface.

Most high-clay waste material has high SAR values. These SAR values may also be associated with high sodium levels. Such soil salinity causes dispersal of clays which plugs pores and reduces infiltration. High SAR and salinity are two factors of greatest concern in reclamation efforts.

Treatment of high SAR in expansive clays is commonly done by the replacement of sodium with some form of calcium (U.S. Salinity Laboratory, 1954). Adequate leaching needed to cause this replacement requires the application of amendments for several years at low rates coupled with adequate irrigation (Hoffman, 1981). Without irrigation in a semi-arid environment, many more years would be required to elevate sodic conditions. The necessity of irrigation and the discontinuous nature of these waste sites in the study area makes such a technique infeasible.

An alternative and much more practical solution to the problem is to bury these wastes below the root zone. Proper burial depths will depend on the rooting depth of the proposed plant cover.

Boron toxicity varies for different plants growing under similar soil conditions and for the same plant under different soil conditions. In general, soil acidity increases boron availability.

Liming is the recommended amendment for boron-rich waste material in the Milk River coal field. Mixing with low boron material is equally suitable if this material does not contribute to overall reductions in pH.

Coal waste material has sufficiently coarse texture to cause water stress and low fertility. Water stress together with high salinity, pH, and boron reduce revegetation potential of these materials.

Mixing with suitably textured soil or burial are both means to alleviate textural problems. Such measures will also treat associated soil limitations such as salinity, pH, etc. Both methods are proposed for the Milk River coal field's coarse textured waste piles: burial for large piles and mixing for areas where the material is less than two feet over native soil.

2. Proposed Ammendments

Harwood (1979) indicated that topsoiling is usually required for successful revegetation of abandoned mine wastes. Generally, the topsoil should be selected for its texture, available water holding capacity, organic content, workability, spreadability, and tilth. The depth of topsoil recommended for successful revegetation varies widely in the literature. However, the topsoil depth must be adequate to support full development of the roots of seeded species. McAllister (1981) reviewed many studies in which topsoiling was found to aid plant establishment and provide a source of rhizomes, seeds, and root material.

Burial depths will be either one or two feet depending on whether native grasses or dryland crops are to be planted. Acidity material or material with elevated boron levels should be limed before burial.

Based on acid-base analysis a 5 ton/acre liming rate is recommended. High boron material should be limed with slightly greater amounts (7 tons/acre) to reduce the potential for plant uptake.

Once wastes have been thoroughly mixed or covered by local materials, the disturbed surface will need more preparation for planting. In most cases the treatment will be little more than required for planting a crop on heavily cropped farmland. Fertility levels will be considered low to moderate for all materials because stockpiled topsoil may be diluted some by subsoils. Application of 40 pounds per acre (lb/a) nitrogen as elemental N, 50 lb/a phosphorus as P_2O_5 and 30 lb/a potassium as K_2O. The addition of a low nitrogen organic mulch, such as straw, at 1 ton/a would require an additional 20 lb/a of nitrogen (N). The final fertilizer (at a rate of 60-50-30, assuming straw mulch) could be derived from a variety of organic or inorganic fertilizers (Appendix B).

F. REVEGETATION

Technologies are available to establish a permanent vegetative cover on abandoned mine sites (Aldon, 1978; Brown and Johnston, 1978). The appropriate technology for a given case depends, in large measure, on the objectives of the reclamation project. In the case of abandoned coal mines in the Milk River Coal Field, the objectives of reclamation are to deter overland flow and subsequent surface erosion, and to restore the productivity of these sites in a way compatible with the desired land use. To accomplish this, the sites need to be shaped and graded to control water runoff, treated with appropriate soil amendments and/or topsoiled, surface mulched, and seeded with adapted plant species using the correct seeding techniques (Harwood, 1979).

McAllister (1981) reviewed several studies evaluating the use of various surface mulches for erosion control and protection of seedlings. Mulching with standing stubble of small grains has been quite successful because the root production provides for soil stabilization. Crimped straw has also been quite successful. Native hay mulch has value because it is a source of native plant seed. Hydromulching with

wood fiber is recommended for steep slopes inaccessible to heavy equipment.

Species used in revegetation must be adapted to the climate and soils of the area and be compatible with the desired land use. Legumes should be included in the seeding mixtures to provide a continuous source of soil nitrogen (Bradshaw, 1980).

The season of planting should generally preceed the longest period of favorable growing conditions (Vallentine, 1980). In the Milk River Coal Field, this would be done in the fall or early spring.

Late fall seedings are recommended for this project because seed dormancy and germination requirements of the cool-season grasses will be met during the winter, and the subsequent early spring germination will precede the most favorable soil moisture conditions.

Seeding methods available include drill and broadcast seeding. Drill seeding favors larger seeded species because it places seed uniformly at a specified depth while broadcast seeding favors a variety of species because seeds are placed at different depths and in different microsites (Vallentine, 1980). Drilling will be done for this project where slope and topography permit because of generally better establishment with this method. Drilling results in even distribution of seed and assures good contact of seed with the soil. Broadcast seeding is quite versatile because it can be done by hand (Cyclone Seeder), by machine (Brillion Seeder-Packer), and on very steep slopes (Hydroseeder). Broadcast seeding will be done on steep slopes (greater than 3:1) and very small areas.

The plant species selected for use in revegetation were based on value in soil stabilization, project land use, and soil/spoil conditions present in the area (Table 4). The seed used should have the highest purity and germination rates available. Seed sources have been presented by McAllister (1981) and Westech/Hydrometrics (1982). Seed should be

obtained from sources within 300 miles north or south of the study area and 500 miles east or west (USDA-SCS, 1978). Legume seed must be inoculated with the appropriate rhyzobium so that nitrogen fixation is maximized.

TABLE 4. Seed mixtures.

Upland Seed Mixture:

Species	Variety	Seed Mix (lbs PLS/acre)
Western wheatgrass	Rosanna	5.0
Thickspike wheatgrass	Critanna	3.8
Blue grama	Lovington	0.4
Sanfoin	Remant (in hulls)	6.9

Coulee Seed Mixture:

Species	Variety	Seed Mix (lbs PLS/acre)
Tall wheatgrass	Alkar, Orbit	8.7
Western wheatgrass	Rosanna	3.8
Streambank wheatgrass	Sodar	2.7
Sweet clover	Camino, Denta, Madrid	0.5

Seedbed preparation will be done as soon as possible following placement of topsoil, addition of ammendments, and fertilization. The seedbed should be chisel-plowed or disced, and harrowed to eliminate clods and produce a firm, smooth surface. Steep slopes, requiring broadcast seeding, may be left with a more irregular seedbed to prevent soil movement and to provide a variety of microsites for germination. A weighted spike harrow effectively prepares such slopes for seeding.

Seeding will be done using hand seeders, hydroseeders, a Brillion grass seeder, or a grass drill, depending on the size and slope of the area. On slopes not exceeding 3:1, a drill or Brillion seeder is recommended to maximize seed contact with the soil and evenness of planting depth and distribution. Drills should be equipped with agitators, depth bands, a seed-metering device, and packer wheels.

One to one-half ton per acre of straw mulch or native hay will be applied over the seeding and crimped vertically into the soil. Steeper slopes should be broadcast seeded by hand or with a hydroseeder. Seed will be covered by harrowing if possible and mulched with one ton per acre of straw or native hay.

1. Revegetation Unit 1 - Upland Grassland

This seed mixture has been chosen to accommodate the upland soil conditions expected at the reclamation sites. The rhizomatous nature of the species make them well suited for these conditions. Western wheatgrass and blue grama are naturally occurring grasses in the area. The other dominant species found here, needle-and-thread, is a rapid colonizer and should reinvade the reclaimed sites quickly. Sanfoin has been added to provide a steady source of soil nitrogen.

Seed will be drilled on slopes less than 3:1 after preparation of a firm, weed-free seedbed in which fetilizer has been incorporated. Planting depth will be one-half inch. Drilling will be done on the contour. Legume seed will be planted in separate rows from the grasses. Sites will then be mulched with one-half ton per acre of straw or native hay.

Seed will be broadcast on slopes greater than 3:1. The seedbed may be left in a roughened condition so that natural sloughing covers the seed. If possible a harrow will be used to cover the seed. The seedbed will then be mulched with one ton per acre of straw, native hay, or wood fiber, and anchored with netting or a chemical tackifier.

2. Revegetation Unit 2 - Coulee

Species in this mixture were chosen for their value in site stabilization, resistance to siltation and grazing, and salt tolerance.

Seed will be drilled on slopes less than 3:1 into a well-prepared seedbed. Drilling will be accomplished in two phases. The first will be on the contour at half the seeding rate and the second at an angle to

the first at half the seeding rate. The seeding will then be mulched with one-half ton per acre of straw or native hay mulch.

Seed will be broadcast and mulched on steeper slopes as described for the Upland Grassland mixture.

G. MONITORING AND MANAGEMENT

It is important to evaluate reclamation success and intercede if failure is a possibility. A regular monitoring program should be established to judge the effectiveness of the reclamation effort. Since soil stability is, in most cases, dependent on the successful establishment of a permanent vegetative cover, this factor should be periodically monitored visually or with a photographic record. Specific methods of evaluating seedling success are given by Vallentine (1980) and the Interagency Forage, Conservation, and Wildlife Handbook (1977). The following criteria for evaluating the seedlings are appropriate to the study area: good (more than one seedling established per square foot); fair (0.5 to 1 per square foot); poor (less than 0.5 per square foot). Unsuccessful revegetation of an area may necessitate a soil monitoring program to identify the cause of failure.

The presence of lush vegetation on revegetated areas will attract wildlife. Provisions need to be made to restrict wildlife use. This can be most effectively accomplished through the use of big game proof fence around reseeded areas. Wildlife enclosures should remain in place two to three years to ensure adequate time for stabilization.

VI. RECLAMATION PLAN

The impacts at all the mines studied fall into three categories. The first category is safety hazards such as open air shafts and adits. The second is hydrologic impacts, such as the mine drainage at the Radar mine. The last, and most common type of impact, is loss of agricultural land due to unvegetated spoil piles, adits, and areas covered with coal waste or mine debris.

All safety hazards are addressed in the reclamation plan. Hydrologic and agricultural problems are addressed on a case by case basis. Reclamation is recommended if the landowner thinks the specific area is important and if the area can actually be significantly improved economically.

A. RECLAMATION PLANS BY SITE

1. Milk River Mine

The only remaining impacts at the Milk River Mine are an open air shaft and the loss of approximately seven acres of potential farmland due to a covering by coal waste.

The open air shaft (33N.19E.7bcdb.) is considered a significant safety hazard and needs to be closed. A concrete cone is best suited for this purpose.

The acreage covered with coal waste is currently used as a junk car disposal site. Reclaiming this area will not improve its current function nor will it increase the probability of it being converted to farmland because of its small size. It is therefore recommended that nothing be done to this area.

No other impacts were identified at the Milk River Mine and no further reclamation is necessary.

2. Perkins East and West Mines

The impacts identified at both Perkins mines are an exposed gas line in a collapsing adit, several coal waste piles, and the loss of about six acres of agricultural land due to a covering of coal waste and mine debris. The elements of the reclamation plan for the site are outlined in Table 5.

At the east Perkins mine, the exposed gas line and collapsing adit are

considered a significant safety hazard. The gas line will be relocated around the small area which exhibits subsidence features. The relocated line will, for the most part, be south of the mine where no underground workings occur. The roof over the collapsing adit will be dug out, and the adit will be backfilled to prevent further collapse. The procedure will be completed along the adit until a sufficient thickness of overburden remains to ensure future stability.

The east Perkins mine coal waste material, located in the one large waste pile, will be buried in the gas line adit and at the additional burial site (33N.19E.18abbb.). The coal waste on the coulee side slopes northwest of the mine will not be touched because the potential benefit of reclaiming this marginal grazing land is not great.

An additional area on the flat upland adjacent to cropped land (33N.19E.7dcc.) has small waste piles spread across its surface. This area will be reclaimed to cropland.

There are no safety hazards at the west Perkins mine, but the area needs to be reclaimed to become productive grazing land. Coal waste from the one pile and other areas around the mine will be buried in the collasped adit and at the additional burial site (33N.19E.7cdcc.). The one concrete structure within the mine area and the mine debris will be buried.

All cropland and rangeland sites will be reclaimed using the procedure outlined in Table 5.

TABLE 5. Reclamation prescriptions for various sites at the east and west Perkins mines.

Site	Techniques
1. Head of draw 270' north of waste pile at east mine (33N.19E.18abbb).	a. Remove subsoil and topsoil from burial areas. b. Excavate roof over collapsing adit. c. Move coal waste piles to burial sites.

Table 5. concluded.

Site	Techniques
	d. Treat coal with 7 tons/acre lime. e. Cover treated coal with 1 ft. subsoil and 1 ft. topsoil. f. Fill sideslopes should be contoured and covered with 6 in. subsoil and 6 in. topsoil. g. Fertilize at standard rate. h. Mulch at 1 ton/acre. i. Area left for farmer to plant grain.
2. Four acre rectangular area covered by waste material 100 yds. east of landowner's home (33N.19E.7dcc.).	a. Spread waste material to less than 4 in. thickness. b. Mix thoroughly with 4 in. of soil. c. Fertilize at standard rate. d. Mulch at 0.5 ton/acre. e. Area left for farmer to plant grain.
3. Site cleanup of areas around east mine including adits, waste pile site, subsidence, etc. (33N.19E.18abb.).	a. Treat waste with 5 ton/acre lime after placement in adits - treat waste pile site similarly. b. Topsoil with 6in. subsoil and 6 in. of topsoil. c. Fertilize at standard rate. d. Mulch at 0.5 ton/acre. e. Seed with coulee seed mix (Table 4).
4. Move gas line.	a. Relocate gas line around mine. b. Fertilize and mulch. c. Seed with upland seed mix (Table 4).
5. Waste pile and adit site at west mine. (33N.19E.7cd.)	a. Treat with lime at 7 tons/acre. b. Scrape half subsoil and topsoil from borrow area to south of adit site and place on waste material placed in adit opening. Approximately 6 in. of subsoil and 6 in. of topsoil should be used to cover waste material. c. Fertilize borrow and waste areas at standard rate. d. Mulch at 0.5 ton/acre. e. Seed with coulee seed mix (Table 4).

3. Mashke Fox Mine

Two open air shafts (32N.18E.11bcdd.) at the Mashke Fox mine present significant safety hazards. They should be plugged with concrete cones or large boulders.

Although the area has been disturbed by mining, no further reclamation is recommended. Very little coal was removed from the mine and therefore little coal waste remains. Subsidence features appear stable. Unlike other mine sites the disturbed areas are approximately 80 percent revegetated. The land is suitable as grazing land now and would not benefit greatly from reclamation.

4. Radar Mine

Saline mine drainage, two open air shafts, several partially collapsed adits, and the loss of agricultural land due to coal waste material and waterlogging are the identified impacts at the Radar mine. Reclamation is recommended for some of these impacts.

The non-acidic mine discharge is extremely saline and possible abatement methods to reduce its salinity are the same as those used in acid mine drainage abatement. Probably the most practical, but yet unproven, method to use here would be alternate cropping with alfalfa on the postulated recharge area southwest of the mine. Several observation wells should be installed to confirm the recharge hypothesis before the method is considered. It is also possible to construct a gravel-filled cut-off trench near the seeping adit and to pipe the intercepted seepage through the waterlogged area. Neither action is recommended, however, because the benefit of reducing the salinity, if indeed it could be reduced, is not greater than the potential reclamation cost. The proposed alternative to abatement of the discharge is to create a channel to contain the discharge, thereby reducing the area impacted. It is recommended that the impoundment be retained which is currently containing this saline discharge. Under the circumstances present at the site, this appears to be the best course of action.

Other water sources have been developed by the landowner adjacent to the mine area so the mine discharge is not needed for stock watering purposes.

Two open air shafts and three partially collapsed adits present significant safety hazards. The air shafts should be blocked with concrete plugs or boulders. Two adits need to be backfilled. The third adit, located on the south part of the mine area, is actively collapsing. The roof should be removed, and the adit backfilled to prevent further collapse. The procedure will be completed along the adit until sufficient thickness of overburden is encountered to ensure future stability.

Two coal waste piles, other coal waste, and mine debris will be backfilled into the adits. The remainder will be placed in a small hollow on the northeast side of the mine as will any saline material removed from below the adits. All of these areas are above the average level of the ground water table, and therefore further acid and salt will not be leached from these wastes.

Reclamation methods for the coal waste, saline, and other disturbance areas are given in Table 6.

TABLE 6. Prescriptions for various sites at the Radar and Diehl mines.

Site	Techniques
1. Waste piles and the hollow to the northeast of the Radar adits where waste piles are to be placed (31N.19E.5bcb).	a. Remove subsoil and topsoil from burial site and place upon waste once in place. Treat waste with 5 tons/acre lime. b. Fertilize at standard rate. c. Mulch at 1 ton/acre. d. Seed using upland mix (Table 4).
2. Waterlogged areas below seep outlet at Radar mine (31N.19E.bcb and 6ada.)	a. Create channel. b. Fertilize channel sideslopes at standard rate. c. Mulch at 0.5 ton/acre. d. Seed channel banks using coulee seed mix (Table 4).

Table 6. concluded.

Site	Techniques
3. Fill two open air shafts (31N.19E.5bc.) and collapse subsiding adit (31N.19E.6aba.).	a. Remove subsoil and topsoil from excavation borrow site. b. Excavate roof over adit. c. Backfill with waste material. Treat with 5 tons/acre lime. d. Topsoil with 6 in. subsoil and 6 in. of topsoil. e. Fertilize at standard rate. f. Mulch at 0.5 tons/acre. g. Seed using upland grass mix (Table 4.).

5. Diehl Mine

Impacts at the Diehl mine include two collapsing adits and one coal waste pile. The other waste pile is revegetated and no reclamation treament is needed. The coal waste should be backfilled into the adits and subsidence features. The remainder should be buried near the site. The excavation pit at Radar should be used for cover material. Treatments as in Table 6, #3 should be applied.

SUMMARY

The post-mine environmental impacts associated with sites evaluated in this study include: subsidence, open shafts and adits, mine discharge, and toxic waste material contributing to a loss of potential grazing and cropland. The severity of these impacts varies both in terms of human health and land use.

By virtue of the hazards and proximity to populated areas, the Milk River, Perkins, and Radar mines pose the greatest immediate threat. The Mashke Fox mine site is hazardous but, for the most part, inaccessible to the public.

Loss in land use is most apparent at the Perkins and Radar mine sites. At the Perkins site, a positive economic benefit would be realized by reclamation of this site. The Radar mine's problems emanate, in part, from surrounding cropping practices which cannot be effectively dealt with except by large expenditures of money. Impacts at this mine should be contained and minimized to ensure protection of adjacent undisturbed land.

A document containing engineering plans and specifications accompanies this report.

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APPENDIX A

Table A. Sample location and depth.

Sample*	Mine	Material	Depth (in)
1	Avery	Slack Coal	0-6
2	Avery	Slack Coal	36-48
3	Radar	Waste Material	0-6
4	Radar	Waste Material	0-6
5	Radar	Waste Material	24-36
6	Perkins-E	Slack Coal	0-6
7	Perkins-E	Slack Coal	24-36
8	Perkins-E	Waste Material	0-6
9	Perkins-W	Slack Coal	0-6
10	Milk River	Waste Material	0-6

* See site map for sample location.

Table B. Laboratory data for Milk River Coal Field Waste Material.

Sample:	1	2	3	4	5	6	7	8	9	10
Analysis:										
pH	4.8	4.5	7.1	5.1	4.8	4.8	5.6	5.7	5.2	5.4
SP (%)[a]	76	63	388	141	110	81	69	173	76	84
EC (mmhos/cm)[b]	2.2	1.4	3.3	6.2	10.1	3.4	7.6	4.9	2.0	1.8
SAR[c]	-	-	31	-	43	-	-	2.3	-	12
Sand (%)	72	76	-	42	58	70	66	38	90	74
Clay (%)	16	12	-	18	22	12	16	40	2	6
Org-Carb (%)[d]	61	56	18	36	49	55	41	30	80	67
Selenium ppm	-	-	1.04	-	-	-	-	-	0.02	0.03
Boron ppm	6.9	-	8.9	-	-	18.6	-	-	54.3	52.0
Molybdenum ppm	-	-	0.05	-	-	-	-	-	0.07	-
Acid-Base Pot.[e]	-7	-	-	-	-	-	-	-	+2	+11

[a] SP = saturation percentage
[b] EC = electrical conductivity
[c] SAR = sodium adsorption ratio
[d] Org-Carb = organic carbon from loss on ignitition
[e] Acid-Base Potential (tons $CaC0_3$/1000 tons dry material)

DSL Suspect Levels:

pH	less than 5.5/greater than 8.5
EC	greater than 4.0-8.0
SP	less than 25%/greater than 85%
SAR	great than 13 (high clay)/greater than 16 (low clay)
Textural Class	c, sc, sic, sicl (greater than 35% c, less than 15% s), sil (less than 15% s), si, ls, s
Boron	greater than 5 ppm
Molybdenum	greater than 0.5-1.0 ppm
Selenium	greater than 0.1 ppm

APPENDIX B

FERTILIZATION

From: Millar, C. E., L. N. Turk, and H. D. Foth. 1966. Fundamentals of Soil Science. John Wiley and Sons, New York.

Table A. The principal commercial fertilizer materials supplying nitrogen of synthethic origin.*

Nitrogen Carrier	Nitrogen %	Remarks
Synthetic Inorganic Nitrogen Carriers:		
Sulfate of ammonia	20.5	Also obtained as a by-product from coke ovens.
Nitrate of soda	15.5-16.5	Also a naturally occurring salt found in Chile.
Calcium nitrate (ANL)	13.0-15.5	Also called nitrate of lime.
Cal-Nitro	16.0-20.5	Ammonium nitrate mixed with $CaCO_3$.
Calurea	34.0	A compound of calcium nitrate and urea.
Ammonium sulfate-nitrate	26.0	A double salt of $(NH_4)_2 SO_4$ and $NH_4 NO_3$.
Ammonium nitrate	33.0-35.0	Conditioned to resist adsorption of moisture.
Ammonium chloride	26.2	Similar to fertilizer properties to $(NH_4)_2 SO_4$.
Anhydrous liquid ammonia	82.2	Used for ammoniating purposes.
Ammonia liquor	24.7	Formed when ammonia is absorbed in water.
Urea-ammonia liquors (UAL-A, B, C, D)	37.0-45.5	Solutions of urea in ammonia liquor.
Crude nitrogen solution	44.0	Sodium nitrate and ammonia dissolved in water.
Nitrogen solution II	37.5	Ammonium nitrate and ammonia dissolved in water.

Table A. concluded.

Nitrogen Carrier	Nitrogen %	Remarks
Synthetic Organic Nitrogen Carriers:		
Calcium cyanamide	21.0-24.0	Sold under the trade name, "Cyanamid".
Urea	45	$CO(NH_2)_2$
Urea-formaldehyde	35-40	Contains insoluble, slowly available nitrogen.

* Other nitrogen carriers are listed with the mixed fertilizers in Table D. that follows.

Table. B. The principal phosphatic materials.*

Material	Percent Available		Remarks
	P_2O_2	P	
Rock phosphate	25-35[a]	11.0-15.4[a]	Effectiveness depends on degree of fineness, soil conditions, and crop grown.
Superphosphate, ordinary	16-20	7.0-8.8	Made by treating ground phosphate rock with liquid H_3SO_4.
Double, treble, or triple superphosphate	40-50	17.6-22.0	Made by treating ground phosphate rock with liquid H_3PO_4.
Basic slag	5-20	2.2-8.8	By-product obtained in the manufacture of steel.
Bone meals	17-30[a]	7.5-13.2[a]	Includes raw as well as steamed bone meals.
Precipitated bone	50	17.6	By-product from manufacture of glue stock from bones.
Bone black	32-45	14.1-15.4	Bones heated in closed retorts.
Bone ash	32-48	14.1-16.7	Bones burned with free access of air.
Calcium metaphosphate	60-65	26.4-28.6	Prepared by treating phosphate rock with hot, gaseous P_2O_5.
Colloidal phosphate	18-23[a]	7.9-10.1[a]	A finely divided, relatively low-grade rock phosphate or phosphatic clay.
Defluorinated phosphate	27-33	11.9-14.5	Prepared from rock phosphate by heating with water vapor or other defluorinating agent; sold under various names.
Fused or calcined	variable	---	Prepared by heating rock phosphate with an alkali or other agent designed to make the phosphorus more available; little fluorine may be removed.

Table C. The principal potassic fertilizer materials.*

Material	Percent Available		Remarks
	K_2O	K	
Potassium chloride	48.0-62.0	39.8-51.5	(Muriate of potash)-the most commonly used potassium fertilizer salt.
Potassium sulfate	47.0-50.0	39.0-41.5	(Sulfate of potash)-usually sells for a higher price than KCl.
Manure salts	19.0-32.0	15.8-26.6	Crude potash salts, mostly in form of KCl.
Kainite	14.0-22.0	11.6-18.3	A semi-refined product of potash manufacture, corresponding to the 20% manure salts.
Sulfate of potash magnesia	25.0-27.0	20.8-22.4	A double sulfate of potash and magnesia.
Tobacco stems	4.0-9.0	3.3-7.5	Includes tobacco stalks and tobacco wastes.
Hardwood ashes	1.5-8.0	1.2-6.6	The potash exists principally as the carbonate.
Potassium metaphosphate	40	17.6	Prepared by heating KCl with phosphoric acid or P_2O_2 and water vapor.

* See Table D. for other potash carriers.

Table D. The analysis of some carriers containing more than one nutrient.

Material	Percent Available					Remarks
	N	P_2O_2	P	K_2O	K	
Potassium nitrate	14	0	--	45	37.3	Occurs only as small natural deposits.
Potassium ammonium nitrate	16	0	--	27	22.4	Essentially a mixture of KCl and NH_4NO_3.
Nitrate of soda potash	14-15	0	--	10-13	8.3-10.8	A constituent of Chilean salt deposits.
Potassium meta-phosphate	0	60	26.4	40	33.2	Prepared from KCl and H_3PO_4 or hot HPO_3.
Monoammonium phosphate	11	60	26.4	0	--	Sold largely as a constituent Ammo-Phos.
Diammonium phosphate	21	53	23.3	0	--	Stable when made from relatively pure phosphoric acid and ammonia.
Ammoniated super-phosphate	3	16	7.0	0	--	Analysis will vary with the amount of ammonia added.
Nitrated super-phosphate	5-6	16-17	7.0-7.5	0	--	Superphosphate treated with nitrogen solution II (see Table 4).

Table E. The principal nonsynthetic organic fertilizer materials.

Material	N	P_2O_5	Percent P	K_2O	K
Dried blood	9.0-14.0	0.3-1.5	0.1-0.7	0.5-0.8	0.4-0.7
Animal tankage	5.0-10.0	3.0-13.0	1.3-5.7	small amts.	small amts.
Garbage tankage	2.0-4.0	1.0-3.0	0.4-1.3	0.5-1.5	0.4-1.2
Process tankages	6.5-10.0	variable	--	small amts.	small amts.
Fish scrap, dried	6.5-10.0	4.0-8.0	1.8-3.5	small amts.	small amts.
Sewage sludge, ordinary	1.6-3.3	1.0	0.4	small amts.	small amts.
Sewage sludge, activated	4.1-7.5	2.5-4.0	1.1-1.8	0.75	0.8-1.7
Cottonseed meal	6.0-9.0	2.0-3.0	0.9-1.3	1.0-2.0	0.9-1.7
Bone meals	0.7-5.3	17.0-30.0	7.5-13.2	--	--
Castor pomace	4.0-7.0	1.0-1.5	0.4-0.7	1.0-1.5	0.8-1.2
Coca shell meal	2.5	1.0	0.4	2.5	2.1
Tobacco stems	1.3-1.6	0.9	0.4	4.0-9.0	3.3-7.5
Sheep or cow manure, dried and pulverized	1.0-2.0	1.0-2.0	0.4-0.9	2.0-3.0	1.7-2.5
Poultry manure, dried	5.0-6.0	2.0-3.0	0.9-1.3	1.0-2.0	0.8-1.7